COOPERATION ON CLIMATE CHANGE UNDER ECONOMIC LINKAGES

Jan Kersting, Vicki Duscha, Matthias Weitzel
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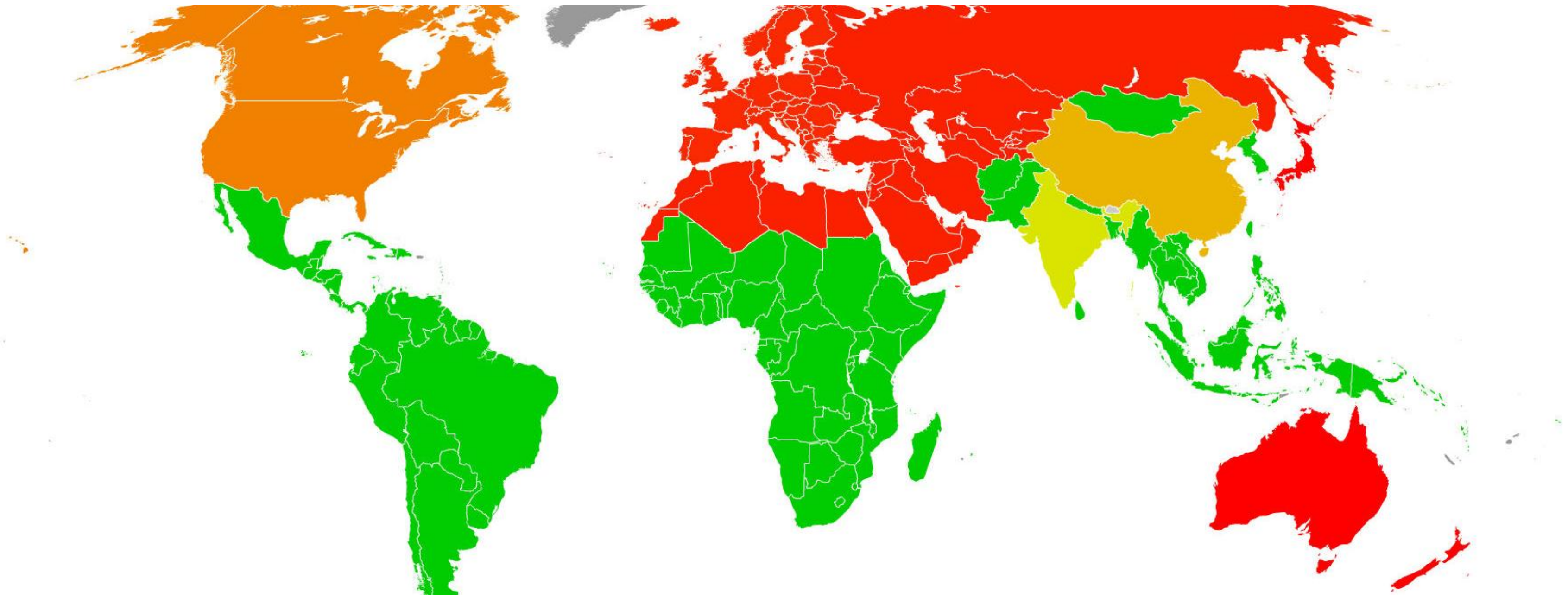

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Background: Game-theoretic models of international climate negotiations

- Countries choose GHG emission level to optimize their own utility
  - Mitigation costs of emission reduction measures
  - Damages from climate change
- Countries may form coalitions. A coalition optimizes joint utility of all its members.

- Different concepts exist regarding the *stability* of coalitions. They come to vastly different results.

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Background: Stability concepts

- *Internal & External Stability* (Barrett, Carraro, Finus, etc.)
  - Countries start at uncooperative equilibrium.
  - At each step, countries check if joining or leaving a coalition improves their utility, assuming no further moves happen -> "free-riding" incentives
  - Result: only small coalitions are stable. Confirmed by numerical models.
  - Modified models (incl. technology transfer, trade restrictions, border-carbon-adjustments, deposit-refund-system, etc.) lead to more optimistic results
- *Core Stability* (Chander, Tulkens, Eyckmans, Bréchet)
  - Countries start at agreement proposal involving all countries (the "grand coalition" **N**)
  - Each possible coalition of countries compares agreement to its own utility (*value*), assuming a rejection would cause grand coalition to fall apart
    - ➢ unanimity rule, similar to UNFCCC
    - ➢ no "free-riding"
  - Result: a stable agreement always exists. Confirmed by numerical models.
  - Modified models: N/A

Agenda

- Background
- A weakness of the *Core Stability* concept
- Methodology
- Results
- Conclusion

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A weakness of the *Core Stability* concept

- Models are based on balancing of consumption loss (**C**) and damages from climate change (**D**)
- In the models using the Core Stability concept, consumption loss only depends on each countries own emissions

$$C_i = C_i(E_i)$$

- This assumption is not realistic: international competitiveness, fossil fuel prices, technological spillovers / learning curves, etc.
- Solution: incorporate economic effects of emission reduction measures in other countries

$$C_i = C_i(E), \qquad E = (E_1, \dots, E_n)$$

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Methodology

- Use global CGE model DART to calculate the consumption function
  - 8 regions: NAM, EUR, ANZ, JPN, EXP, CHN, IND, ROW
  - Time frame: 2013 – 2050. Extrapolation of emissions to 2300 in order to represent long-term damages from climate change
  - Output: consumption changes for different emission reduction targets for each of the 255 possible coalitions
- Damage functions from RICE model (Nordhaus 2010), based on cumulative emissions for each year
  - For warming of 2°C, RICE predicts global damages of 2.0% of consumption
  - IPCC report: 0.2%-2.0% damages for 2°C warming
  - ➢ Additional “Low Damages Scenario“ with damages 10% as high as in RICE

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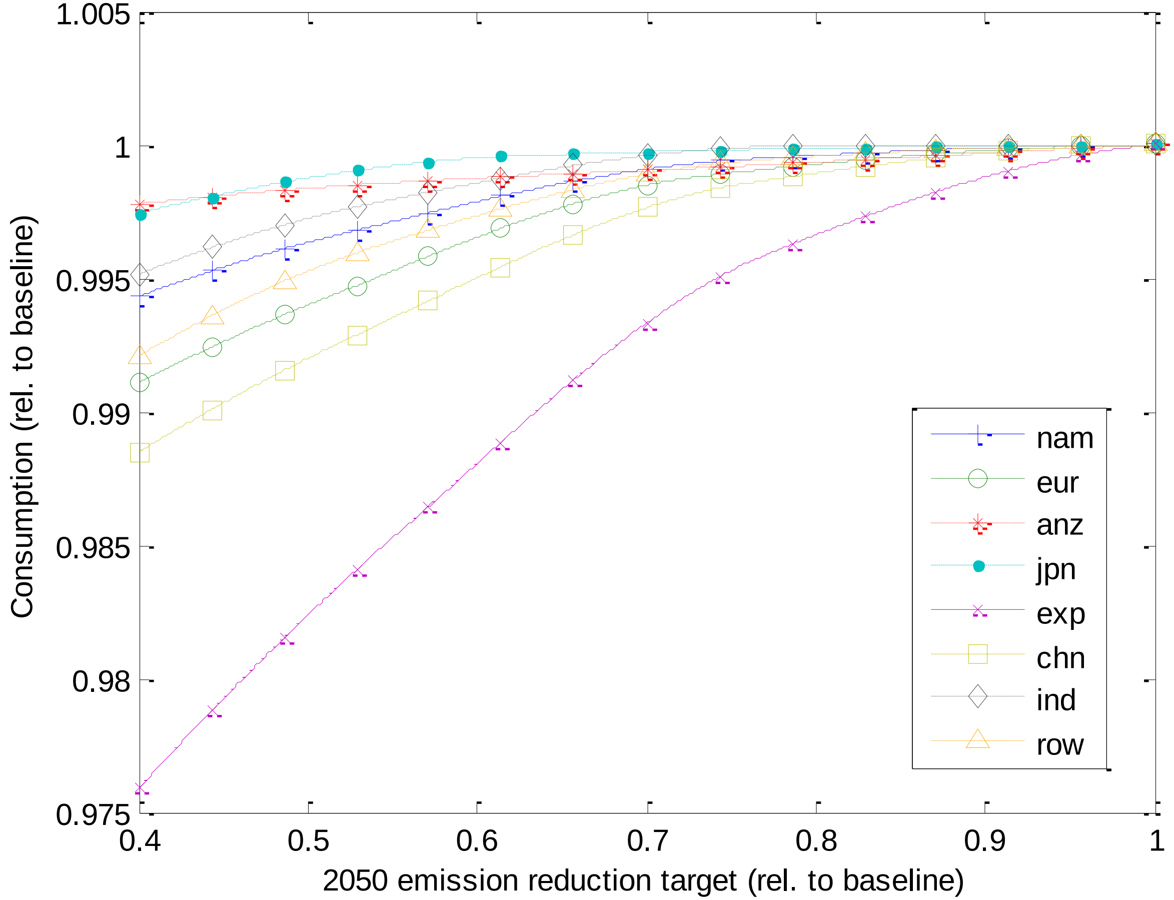
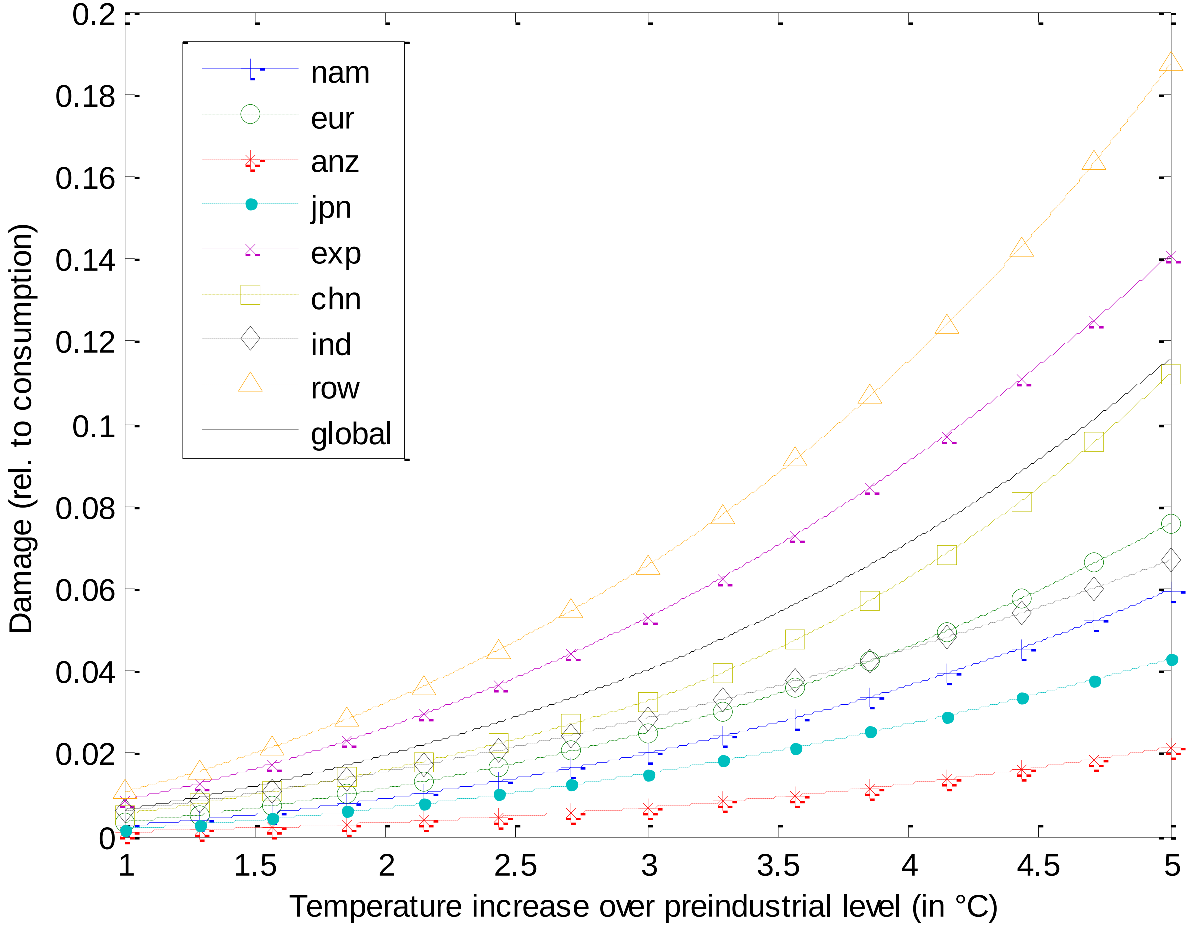
Methodology II

- Calculation of equilibrium **for each coalition**
- Control variable: emission target in 2050 (rel. to baseline)
- Parallel optimization of targets for the coalition and for all "outsiders"
- ➢ Utility = Consumption – Damages, for each coalition in equilibrium, defines cooperative game
- Check existence of stable global agreement
  - Calculate "best partition" of the game (partition = set of disjoint coalitions)
  - Compare with grand coalition
  - ➢ If best partition is better than grand coalition, then no stable agreement exists.

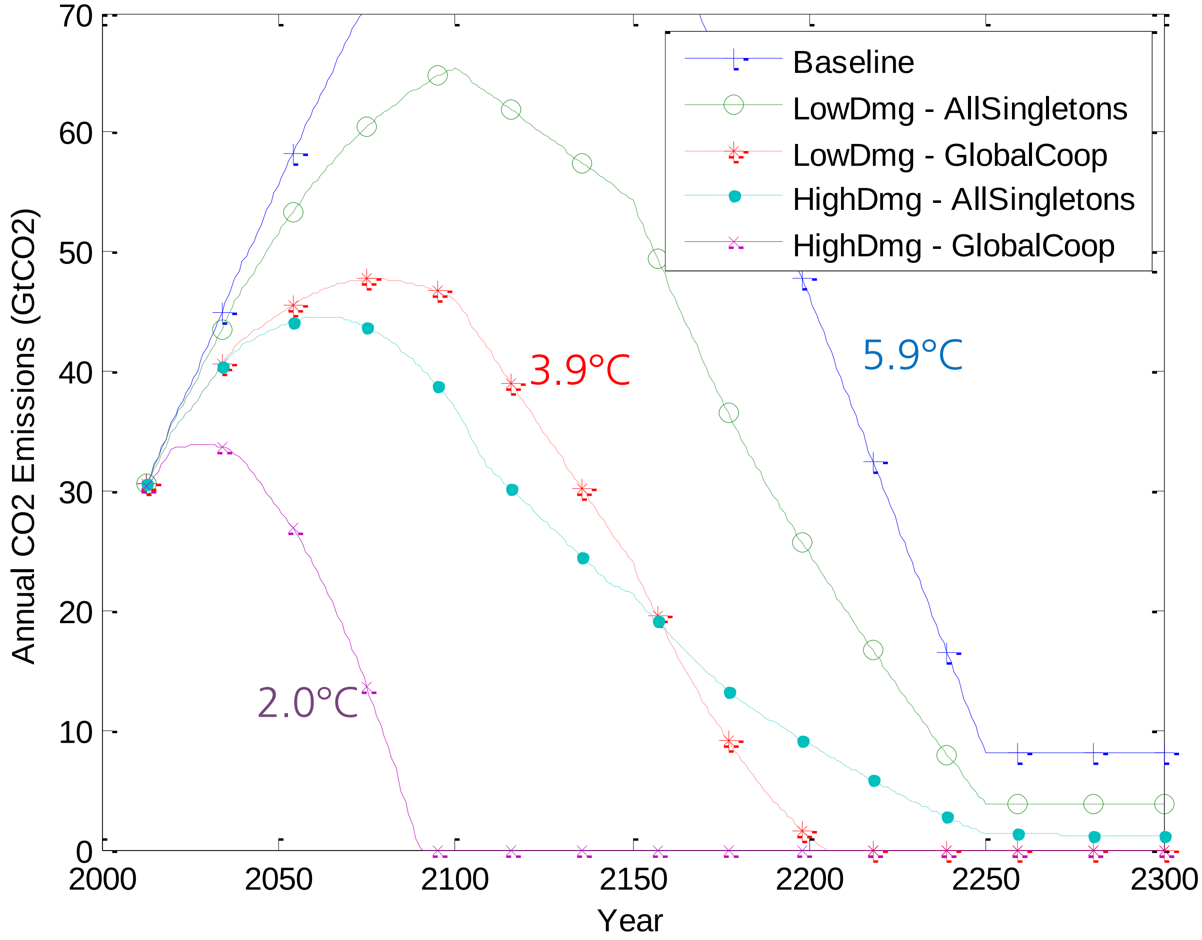
Consumption functions for "singleton" coalitions



Damage functions



Benchmark cases – Global CO2 emissions



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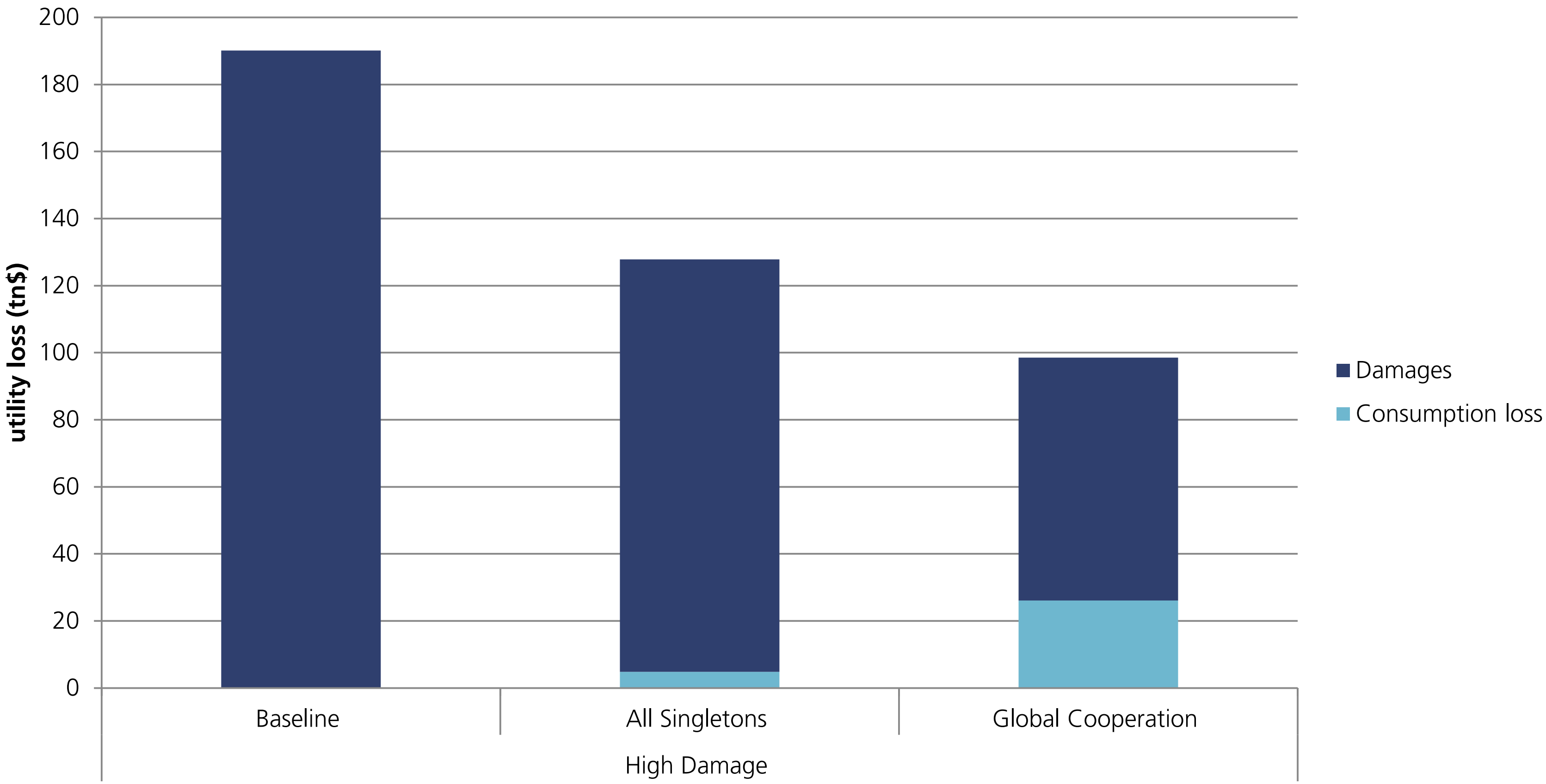
Impacts of global cooperation – High Damages Scenario



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Low Damages Scenario

		2050 emission target (rel. to baseline)	Utility loss (tn$2007)
Partition “Global Cooperation”		**80.26%**	**16.65**
Case “Global Cooperation”	N	80.26%	16.65
Partition “All except EUR, ANZ, EXP”		**82.05%**	**16.17**
Case “Partial Cooperation”	N \ {EUR, ANZ, EXP}	75.71%	12.62
Case “All Singletons”	{EUR}	100.00%	1.29
	{ANZ}	100.00%	0.03
	{EXP}	100.00%	2.24

- Grand coalition is not best partition
- ➢ no stable global agreement exists, contrary to classic theoretical model

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Low Damages Scenario II

- Global cooperation creates surplus (on global level)
- Surplus has to be divided to cover two cases simultaneously
  - Case 1: "All Singletons"
    - Fossil fuel exporters (ANZ, EXP) suffer from drop in fossil fuel prices, if emissions are reduced globally -> prefer no cooperation
    - Due to unanimity requirement, they can block any global agreement, which does not compensate them adequately
    - Compensation would have to come from regions, which benefit from global emission reductions
  - Case 2: "Partial Cooperation"
    - These regions have alternative to form "coalition of the willing"
    - Global emissions are only slightly higher than in case of global cooperation
    - ➢ Additional benefit from move to global cooperation not enough to compensate fossil fuel exporters
- Europe: high emission reduction costs, low damages -> prefers "All Singletons" to joining coalition of the willing

High Damages Scenario

	2050 emission target (rel. to baseline)	Utility loss of coalition or partition (tn$2007)
Partition “Global Cooperation”	**51.28%**	**98.56**
N	51.28%	98.56
Partition “All except EXP”	**57.99%**	**110.10**
N \ {EXP}	51.11%	92.64
{EXP}	95.41%	17.46
Partition “All except EUR, ANZ, EXP”	**57.32%**	**115.31**
N \ {EUR, ANZ, EXP}	50.36%	87.72
{EUR}	94.14%	9.95
{ANZ}	100.00%	0.18
{EXP}	95.41%	17.46

- Grand coalition is best partition -> stable agreement is possible
- High damages lead to high gains of cooperation
- Fossil fuel exporters region: second highest damages of all regions
- Emission target of “coalition of the willing” is almost unaffected by inclusion of EUR, ANZ and EXP

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Conclusion

- Current models using the *core stability* concept miss inter-regional economic implications of emission reduction measures
- Our model incorporates these effects
- In a scenario with low damages, no stable global agreement is possible in the resulting cooperative game, in contrast to the theoretical model and existing numerical models
- Global cooperation is blocked by fossil fuel exporters, who lose revenue if international emission reduction measures are enacted
- This result meshes better with models using the *internal and external* stability concept
- In a scenario with high damages, global cooperation is still possible, as the gains from cooperation are substantially higher

Thank you!

Contact:

Jan Kersting

Fraunhofer Institute for Systems and Innovation Research ISI

Mail: jan.kersting@isi.fraunhofer.de

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BACKUP

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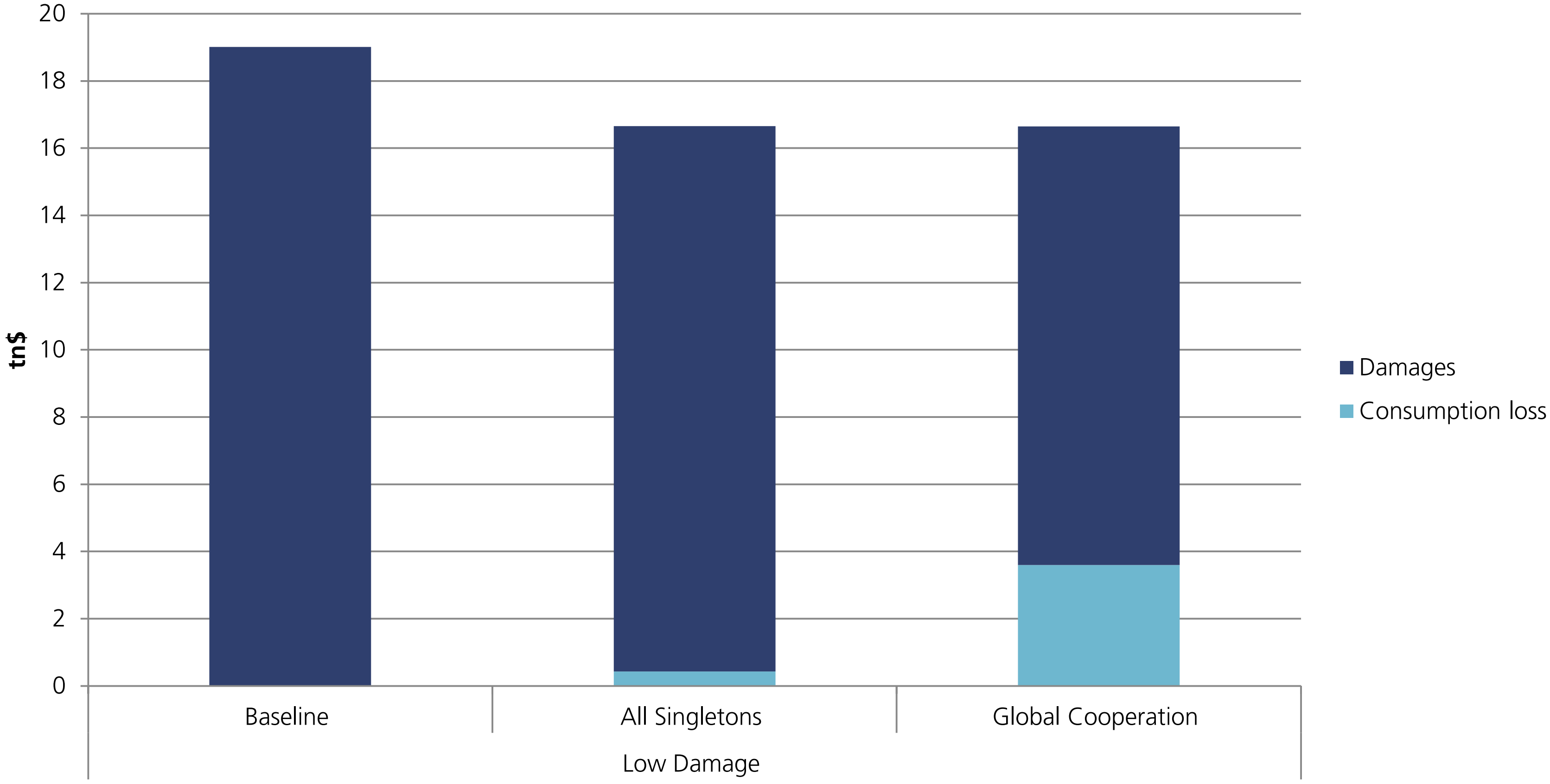
Impacts of global cooperation – low damages



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Targets

	Low damages scenario		High damages scenario	
	2050 emission target (rel. to baseline)	Utility loss of coalition or partition (tn$)	2050 emission target (rel. to baseline)	Utility loss of coalition or partition (tn$)
Partition "Global Cooperation"	**80.26%**	**16.65**	**51.28%**	**98.56**
N	80.26%	16.65	51.28%	98.56
Partition "All Singletons"	**92.69%**	**16.66**	**78.51%**	**127.85**
{NAM}	100.00%	1.39	83.26%	10.72
{EUR}	100.00%	1.29	94.14%	9.95
{ANZ}	100.00%	0.03	100.00%	0.18
{JPN}	100.00%	0.11	99.49%	0.87
{EXP}	100.00%	2.24	95.41%	17.46
{CHN}	98.28%	1.41	77.12%	10.84
{IND}	77.79%	0.92	71.13%	7.30
{ROW}	84.26%	9.29	60.82%	70.53

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Example of cooperative game with empty core

Coalition	Player			Value of coalition
	1	**2**	**3**	
{1}	1	1	2	1
{2}	1	1	2	1
{3}	1	1	**2**	**2**
{1,2}	**2**	**2**	1	**4**
{1,3}	2	1	2	4
{2,3}	1	2	2	4
{1,2,3}	1.5	1.5	2.5	5.5

Core-stable imputation in the high damages scenario (utility loss in tn$)

Region	Allocated amount
NAM	5.96
EUR	5.19
ANZ	-0.18
JPN	0.50
EXP	12.70
CHN	6.08
IND	2.54
ROW	65.77

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